

Evaluation of ultrasound for central venous access in ICU by an in experienced trainee

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Abstract

Background and Aims: Central venous catheter placement is an important procedure for ICU (Intensive Care Unit) patients. We studied the usefulness of ultrasonography for placement of central venous catheter by in-experienced anesthetists. **Materials and Methods:** A prospective observational study of 32 patients requiring central venous access (CVA) in surgical ICU (SICU). Data collected were patient's demographics, indication, type of catheter, success rate, attempts, complication rate and access time were recorded and compared with other studies. **Result:** The overall success rate was 89.5% in the IJV (Internal Jugular Vein) and 92.3% for SCV (Subclavian Vein) group. The success rates for insertion at first, second, and third attempt were 52.6%, 31.6%, and 5.2% for IJV and 46.2% and 53.8% for SCV. Average number of attempts made for IJV cannulation was 1.74 +/- 1.04 and 1.54 +/- 0.51 for SCV. The total time taken for IJV access was 858.78 +/- 381.9 sec, whereas in the SCV group, it was 984 +/- 328.98 seconds. In our study, overall rate of complication was 21.05% (4/19 patients) for IJV and 23.07% (3/13 patients) for SCV insertion. Incidence of various complications like arterial puncture, misplacement of CVC, hematoma, pneumothorax, and hemothorax were also noted. **Conclusion:** This study concludes that real time ultrasound guidance during IJV and SCV cannulation can achieve higher success rate, fewer complications, number of attempts, and failure rate among inexperienced anesthetists.

Keywords: Central venous catheter, inexperienced, intensive care unit, ultrasonography

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Introduction

In the United States, physicians insert more than 5 million central venous catheters every year^[1] with an associated complication rate of >15%.^[2-5] Central venous access is routinely practiced for hemodynamic monitoring, delivery of blood products and drugs (e.g., chemotherapy and antibiotics), hemodialysis, total parenteral nutrition, and management of peri-operative fluids. Central lines are typically introduced into the internal jugular, sub-clavian, or femoral veins. Many anatomic landmark-guided techniques (ALT) for IJV puncture have been described.^[6] Unfortunately, the use

of central venous catheters is associated with adverse events that are both hazardous to patients and expensive to treat.^[7] At the time of insertion, complications, including death, are influenced by patient factors such as Body Mass Index (BMI), site of attempted access, and operator experience.^[8] It has been suggested that ultrasound guidance (USG) could improve the success rate, reduce the number of needle passes, and decrease complications.^[9-11]

Ultrasound (US) has been evaluated as an adjunct to central venous access under routine circumstances of central venous cannulation. The authors of these studies found that ultrasound guidance facilitates a higher success rate with a lower complication rate.^[12]

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Importance

Historically, performing blind puncture procedures depended greatly on a correct knowledge of vascular anatomy and clinical experience. Even with experienced operators, complication rates up to 12.3% have been

reported for CVC insertion using the conventional landmark technique.^[6] Thus, as early as in 1984, authors have recommended utilizing ultrasound guidance to optimize the success rate of cannulations and to minimize complications.^[13] There is an increasing body of evidence supporting the use of US for CVA. The Agency for Healthcare Research and Quality in USA and the United Kingdom have recommended the use of US guidance for CVA as one of the practices to improve patient care.^[14,15] Advances in specialty care in India and the availability of portable US units in hospitals have made use of US for bedside procedures, possible in many institutes.

Goals of study

The goal of this study was to analyze the usefulness of US guidance for CVA among inexperienced anesthetists, to determine success rate, complication rate, number of attempts, and time for CVA.

Materials and Methods

Methodology

This is a prospective observational study performed at SICU of a tertiary care hospital in India.

This study was approved by the ethics committee of the hospital. Written and informed consent was obtained for all participants. All catheters were placed by 2nd and 3rd year residents of anesthesiology in the presence of a consultant experienced in this procedure. Trainees were inexperienced in CVC placement for either ALT or US-guided technique. The trainee had observed and assisted an experienced Intensivist initially for at least 10 line insertions before performing the procedure. A total of 32 patients were enrolled between January 2011 and June 2012.

All patients admitted to SICU and requiring CVA as part of their management between January 2011 and June 2012 were enrolled for the study.

Exclusion criteria

- <18 years of age or >90 years of age
- Where consent was not given
- Lines placed in dire emergency
- Infection at local site
- Vasculitis
- Chronic obstructive pulmonary disease (COPD) for SCV
- Injury or previous surgery to IJV/SCV
- Presence of a pacemaker.

Method

Operators with <6 years experience in CVC were classified as inexperienced, and the operators with >6 years of experience were classified as consultants. Demographic characteristics, such as age, gender, weight, diagnosis, blood pressure, ECG (electrocardiography), coagulation parameters (PT/INR), were recorded for all patients.

The measured outcomes were the access time, the number of attempts for successful placement, complications, such as carotid artery puncture, skin hematoma, pneumothorax, and hemothorax, difficulties in passing CVC.

The whole procedure of CVC insertion was timed meticulously, and the measured outcome of "Access time (T)" was divided into 6 time-intervals (Ta, Tb, Tc, Td, Te, Tf), wherein,

- Ta = Time to confirm sono-anatomy before applying anti-septic solution,
- Tb = Local infiltration to putting sterile probe,
- Tc = Putting sterile probe to insertion of needle,
- Td = Insertion of needle to successful aspiration of venous blood,
- Te = Insertion of guide wire to removal of needle,
- Tf = Insertion of CVC to aspiration of blood through all ports.

While performing SCV cannulation, before removing needle, misplacement of guidewire was confirmed by putting US probe over ipsilateral IJV.

Wastage of time was considered as loss of time due to any unexpected event during CVC i.e., loss of electric supply, need for change of instruments etc., Wastage of time was deducted from access time. Successful placement was defined as the confirmation of the catheter position by X-ray taken immediately after procedure and functional determinants (i.e., no difficulty in the infusion or aspiration of venous blood).

The patient was placed in the Trendelenburg position. After locating the landmarks—for either IJV or SCV, a non-sterile ultrasound probe was placed over the respective sites to verify the anatomy. Artery and vein were differentiated by viewing the Doppler waveform [Figures 1-4] for compressibility and pulsatility. The IJV can be seen by US with both in-plane and out-of-plane approach, but for SCV, it is difficult to obtain image with the out-of-plane approach because of its anatomical position (below the clavicle). SCV can be seen with the in-plane approach. In this study, we obtained in plane SCV image via infraclavicular route, by applying US

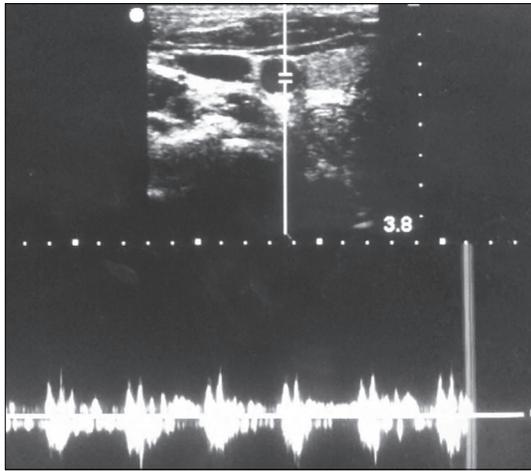


Figure 1: Doppler waveform of carotid artery

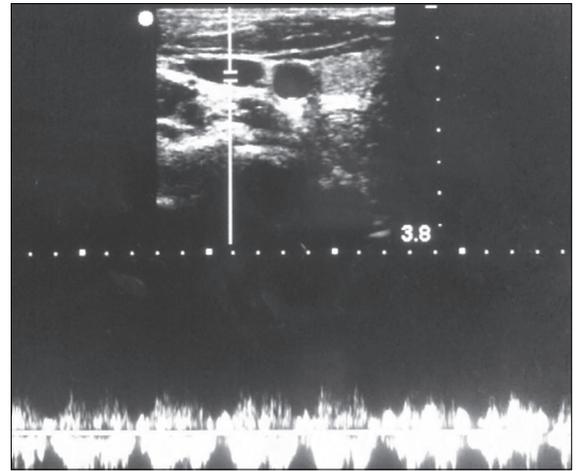


Figure 2: Doppler waveform of IJV

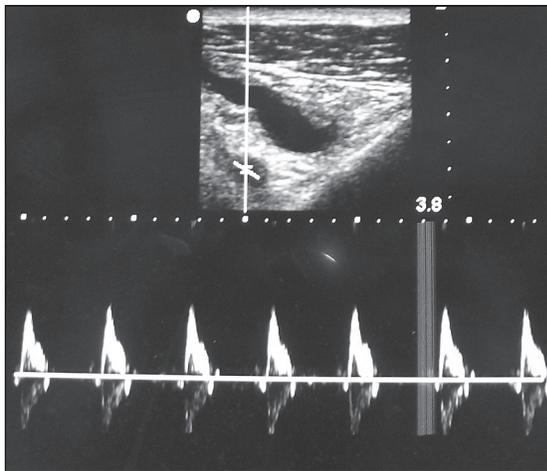


Figure 3: Doppler wave form of SCA

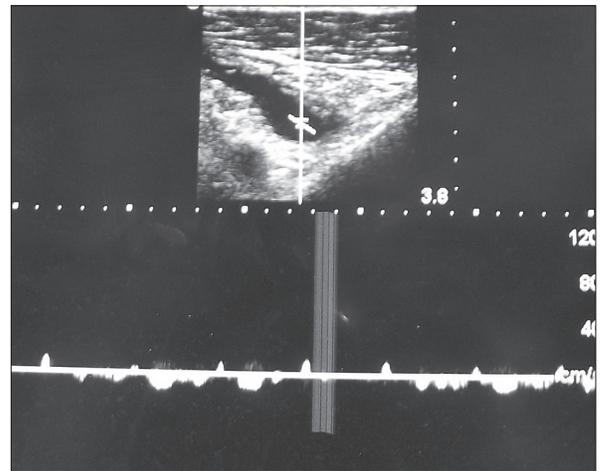


Figure 4: Doppler wave form of SCV

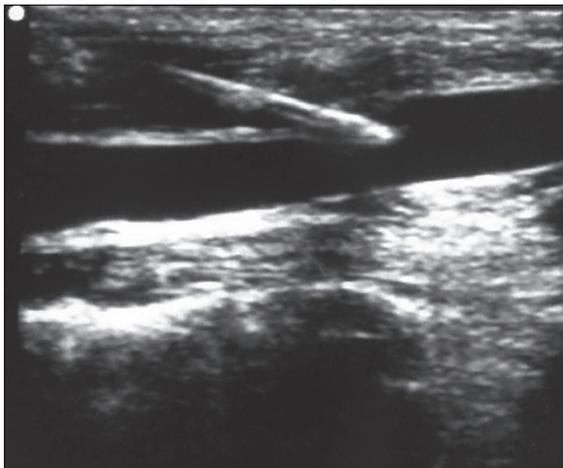


Figure 5: Needle compressing vessel wall

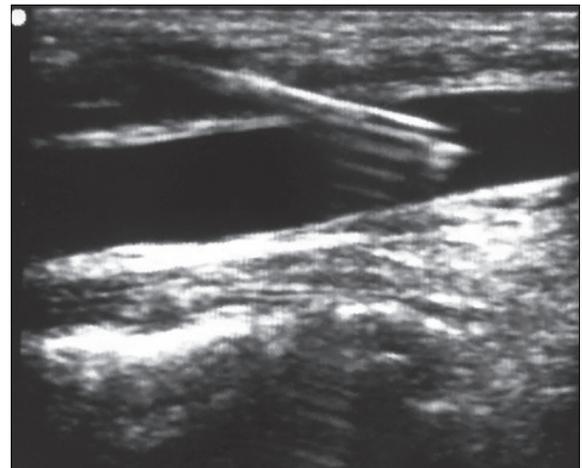


Figure 6: Bevel of needle is in the lumen of vein

probe just below and parallel to clavicle. Puncture of the central line was done under direct US guidance with the in-plane approach. So, needle could be seen either puncturing or compressing the vein [Figures 5 and 6].

The procedure was considered a failure if the operator was unable to perform venous catheterization after 3 attempts, an attempt being defined as the introducer needle's entry into the skin and its removal from the skin.

If the initial method was unsuccessful after a maximum of 3 attempts, help was taken from a more experienced operator, or an alternative site was chosen.

For catheterization, a 7.5-MHz linear array ultrasound probe (Sono Site Micro Maxx ultrasound system) was used. All procedures were performed under the direct observation of a consultant anesthesiologist. Real time ultrasound guidance was used for placement of the catheter. All procedures were performed in non-emergency conditions.

At the end of procedure, all data including patients' demographics, coagulation profile, site of insertion, number of attempts, access time, complications, difficulties during procedure, and failure of procedure were recorded in Performa.

Results

In our study, there were a total of 32 patients who underwent US-guided CVC (19 IJV and 13 SCV) insertions [Table 1]. The success rate for insertion at first attempt was 52.6% for IJV and 46.2% for SCV [Table 2]. At the second attempt for CVC, it was successful in 31.6% for IJV and 53.8% for SCV. In the IJV group, successful insertion occurred at third attempt in 1 patient (5.2%). Overall, in the IJV group, there was failure in 2 patients (10.2%). In the SCV group, no patient required a third attempt for insertion, though the overall failure was in 1 patient (7.6%), and in this case, the procedure was abandoned after the 2nd attempt due to difficulty faced during passing of guide-wire, and such advice was given by the experienced performer, even though, failure was to be considered after 3 attempts. This was done in view of patient's safety.

Hence, the overall success was 89.5% in the IJV and 92.3% for SCV group [Table 2].

Average number of attempts made for IJV cannulation was 1.74+/- 1.04 in all 19 patients and 1.54+/-0.51 for SCV in all 13 patients [Table 2].

The various time-intervals mentioned in the methodology were noted and are displayed in [Table 3]. The total time taken for IJV access was 858.78 +/- 381.9 sec, whereas in the SCV group, it was 984 +/- 328.98 seconds.

In our study, overall rate of complication was 21.05% (4/19 patients) for IJV and 23.07% (3/13 patients) for SCV insertion. Arterial puncture occurred only in 1 patient in each group (5.2% for IJV and 7.7% for SCV).

In only 1 patient (7.6%), misplacement of CVC was detected after SCV cannulation. There was no incidence of hematoma, pneumothorax, and hemothorax in both IJV and SCV groups [Table 4].

Discussion

Use of ultrasound technology is evolving in a big way in various fields of medicine, such as trauma, critical care, and peri-operative evaluation. In the ICU, the role of USG has been established for bedside echocardiography, FAST protocol in trauma victims,

Table 1: Demographic data: Total 32 patients

Parameter	IJV	SCV
Age (years)	44+/-19	50+/-16
Sex (m/f)	14/5	9/4
Weight (kg)	58+/-7	64+/-14
Systolic BP (mmhg)	109.7+/-20.03	119.08+/-19.82
PT (INR)	1.35+/-0.49	1.16+/-0.31
Type of catheter (m/d/t)*	0/2/17	1/1/11

*(m/d/t): mono/duo/trio; IJV: Internal Jugular Vein; SCV : Subclavian Vein, INR: International normalized ratio, PT: Prothrombin time

Table 2: Success rates, average attempts and failure rates in patients undergoing central venous catheter placements

	IJV group	SCV group	P value
Rate of success at 1 st attempt	52.60%	46.20%	0.9966
Rate of success at 2 nd attempt	31.60%	54%	0.3679
Rate of success at 3 rd attempt	10.50%		
Overall success rate	89.50%	92.30%	0.7258
Average no. of attempts at insertion	1.74+/-1.046	1.54+/-0.519	0.5298
Failure rate	10.50%	7.70%	0.7258

IJV: IJV: Internal Jugular Vein; SCV: SCV : Subclavian Vein

Table 3: Procedure time intervals of central venous catheter placements

Time interval (seconds) (mean, SD)	Study group	
	IJV	SCV
Ta	115.16+/-61.92	170+/-86.82
Tb	137.58+/-65.59	132+/-31.04
Tc	99.32+/-53.38	116.69+/-105.71
Td	263.06+/-310.83	194.08+/-167.65
Te	92.11+/-40.81	234.33+/-324.226
Tf	179.72+/-39.48	167+/-91.68
Tt	858.78+/-381.9	984+/-328.98
Tb+c	236.89+/-66.66	249.61+/-99.66
Tb+c+d	486.10+/-330.28	443.69+/-211.37
Tb+c+d+e	573.36+/-346.21	660.0+/-292.2
Tb+c+d+e+f	743.63+/-371.53	814+/-313.52
Tc+d+e	435.78+/-326.42	527.07+/-304.02

IJV: Internal Jugular Vein; SCV : Subclavian Vein; SD: Standard deviation, Time interval: Ta = Time to confirm sono-anatomy before applying anti-septic solution, Tb = Local infiltration to putting sterile probe, Tc = Putting sterile probe to insertion of needle, Td = Insertion of needle to successful aspiration of venous blood, Te = Insertion of guide wire to removal of needle, Tf = Insertion of CVC to aspiration of blood through all ports, Tb+c = Local infiltration to insertion of needle, Tb+c+d = Local infiltration to successful aspiration of venous blood, Tb+c+d+e = Local infiltration to removal of needle, Tb+c+d+e+f = Local infiltration to aspiration of blood through all ports, Tc+d+e = Putting sterile probe to removal of needle

Table 4: Rate of complications of central venous catheter placements

Complications	IJV group (n=19) (%)	SCV group (n=13) (%)	P value
Overall rate of complications	15.7	23.07	0.9493
Hypotension	0	0	
Tachycardia	5.2	0	0.8374
Fall of spo2	0	0	
Cardiac arrest	0	0	
Hematoma	0	0	
Arterial puncture	5.2	7.7	0.6472
Misplacement of cvc	0	7.6	0.8570
Decrease chest expansion	0	0	
Continuous bleeding	0	0	
Injury to thoracic duct	0	0	
Injury to surrounding nerves	0	0	
Air embolism	0	0	
Catheter embolus	0	0	
Pneumothorax	0	0	
Arrhythmia	5.2	7.7	0.6472

IVJ: Internal Jugular Vein; SCV : Subclavian Vein; CVC: central venous

airway examination, papillary examination in swollen eye, detection of various lung conditions, and for vascular access.

IJV and SCV cannulations are commonly practiced in our ICU. In our hospital, being a tertiary care center with an attached teaching Institute, most of these procedures are done by the residents.

In this study, IJV and SCV cannulations were done with real time ultrasound guidance by inexperienced anesthetists under the supervision of an experienced anesthetist to ensure patient safety. All operators who performed the procedure were either in the 2nd or 3rd year of residency in the department of anesthesiology. We also compared the results of IJV vs. SCV group. We had successfully inserted CVC in IJV using USG in 89.5% patients and in 92.3% through the SCV route. In the studies using ALT, the overall success rate for IJV cannulation ranged from 76-97% irrespective of the performer's experience.^[6,10,16-19] In most of the studies using the ALT for SCV cannulation, the success rate was 81-96% with experienced operators.^[6,16,18,20] One study,^[21] with inexperienced operators, had a significantly lower success rate as compared with our USG-guided technique ($P < 0.05$). Hence, using the US improved the success of CVC placement, especially through the SCV route.^[11,20]

Other studies where US was used, the overall success rate for both IJV and SCV cannulation ranged within 69-100%.^[6,9,17-19] In one of the study, where US-guided IJV cannulation was performed, the success rate was higher ($P = < 0.05$), but they had

more experienced performers than ours (experienced attending cardiologists and cardiac fellows).

In our study, successful insertion was achieved at first attempt in 52.6% and 46.2% for IJV and SCV, respectively. In comparison to other studies done with ALT, there was no significant difference at first attempt, either with IJV^[6,17-19,22] or SCV.^[6,23] In two studies done with US for IJV cannulation by experienced performers, there was a higher success rate at first attempt as compared to our study,^[6,18] but with SCV^[6] cannulation, no such difference was found.

At second attempt, we had a success rate of 31.6% for IJV and 54% for SCV cannulation. In one study^[23] using ALT for SCV cannulation, success rate at second attempt was significantly less ($P = < 0.05$) than ours, even though there were experienced operators. Using US for SCV cannulation improves the chances of successful insertion.

To achieve successful insertion in our study, the average numbers of attempts were around 1.5 to 1.7 [Table *2]. In two studies,^[9,18] using US for IJV, significantly fewer number of attempts were reported. This may be attributed to the greater experience. Physicians who employed the USG method were well trained and had at least 5 years of experience with this method.^[9] All cannulations were performed by highly experienced attending cardiologists and cardiac fellows.^[18]

The rate of complications in our study was 4 and 3 patients in IJV and SCV group, respectively, compared favorably with most of the previous landmark-guided studies^[3,6,16,17,23,24] and US-guided studies,^[6,16,17,21] despite the inexperience of our trainees. Only in one study^[16] using ALT, where cannulation was done by the experienced, had significantly fewer complications as compared to ours. In two studies^[6,16] using US, there were significantly fewer complications, out of which one study had experienced performers.^[16]

In our study, 1 patient (5.2%) in IJV group and 1 patient (7.7%) in SCV group had arterial puncture. We found no significant difference in comparison with other studies using either ALT^[3,6,9,10,17-23,25] or US^[6,9,10,17-22,26] for CVC, irrespective of performers' experience. US-guided CVC enabled trainees to perform the procedure without complications.

In our study, only in 1 patient (7.6%), misplacement of CVC was detected after SCV cannulation. This led us to check the misplacement towards the ipsilateral IJV by in-line visualization after passing the guide-wire and

before removing the needle. During SCV cannulation, misplacement to ipsilateral IJV was ruled out by US-guided by in-line visualization of the IJV after passing the guide-wire and before removing the needle. By implementing this protocol, we detected misplaced guide-wires in other two patients at the time of insertion rather than detecting it later by X-ray. The guide-wire could be immediately repositioned and misplacement of the CVC thus prevented. This maneuver/technique enhanced the usefulness of US-guided CVC while not increasing the procedural time significantly ($P < 0.05$).

In our study, none of patients developed complications like hematoma, pneumothorax, and hemothorax in both IJV group and SCV groups. This was not significantly different in other studies, with either technique (ALT^[3,6,9,10,14,16,17,18,20-22,25] or US^[6,9,10,16,17,20-22]). Only Denys and colleagues^[18] had a complication rate of 0.2% for hematoma for IJV cannulation with US guidance by experienced performers, somewhat higher than our study.

Studies have reported pneumothorax as a common complication during SCV cannulation using ALT.^[3,6,14,20,21,23] Relatively lateral position of percutaneous puncture of needle and real time visualization of vein and needle tip in USG technique makes this complication less common.^[11]

Mansfield *et al.*^[27] found that rate of complications after 3 or more attempts was 6 times as compared to first attempt. They had compared standard insertion technique with US-assisted (not US-guided) procedures. Our study was US-guided, and we found complication rates of 10%, 33.3%, and 33.3% on first, second, and three or more attempts, respectively.

The number of needle passes has been strongly associated with complication rates. Mansfield *et al.*^[27] found a complication rate for SCV cannulation of 4.3% with a single needle pass, 10.9% with two passes, and 24% in more than two needle passes. We had 0% with one needle pass and 42.8% with two needle passes.

We had calculated various time intervals during the procedure as shown in table. Comparing corresponding time intervals reported in other studies using ALT, the procedural time was longer ($P < 0.0001$) as compared to experienced^[9,18,20] but similar to inexperienced performers.^[19]

Studies have concluded that USG decreases insertion time.^[9,18,20] In comparison with these studies, performers in our study took longer time for CVA. There are

different recommendations regarding experience on the ultrasound machine.^[28,29] Trainee anesthetists were new to use the ultrasound technic. The sample size was too small for any technic. The usefulness of USG- on reducing CVA-related complications was not studied. Although experience of operator was arbitrarily defined as one having more than 6 years of experience, this may not truly reflect experience of the operator. The only available data relating the actual experience to complications come from the pre-ultrasound era and suggest that operators who have performed >50 CVC have half the complication rate as compared to those who have performed <50 CVC.^[30]

Conclusion

This study of relatively small sample size concludes that real time ultrasound guidance during IJV and SCV cannulation results in higher success rate, fewer complications, attempts, and failure rate with inexperienced anesthetists. We suggest that ultrasound guidance be used for CVA by trainees as well as routinely.

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